

# AUTOMATIC DETECTION OF EPILEPTIFORM DISCHARGES IN EEG USING A BACK-PROPAGATION NETWORK

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**Abstract:** This paper presents an automatic approach to detect epileptiform discharges (ED) in electroencephalogram (EEG). On the algorithm we utilized back-propagation artificial neural network (BPN) to detect ED. We train BPN respectively for each patient and induce parameter  $k$  to determine a threshold value. The result shows that the algorithm can determine presence or absence of ED automatically, and decrease the false determination in current automated approaches as well.

**Keywords:** Epileptiform discharges (ED), back-propagation network (BPN), electroencephalogram (EEG)

## I INTRODUCTION

Electroencephalogram (EEG) is utilized to diagnose epilepsy by determining the presence or absence of epileptiform discharges (ED). Some improvements have been achieved in automated detection of ED, primarily through ruled-based approaches (Gotman et al.<sup>[1]</sup>, Frost Webber et al.<sup>[2]</sup>, etc) and BPN-based approaches (Eberhart et al, Gabor and Seyal<sup>[3]</sup>, Webber et al.<sup>[8]</sup>, Zhang et al, etc). But these approaches produce false interpretation in a high proportion.

ED patterns of epilepsy's EEG are of variances, and change frequently even if for the same patient. Obviously, it is not the best way to detect ED for different patient by the same BPN trained. Experiments demonstrated that the cross recognition method has a low detection rate, which detect epileptiform discharges (ED) of the other epileptic's EEG by the same basic-BPN trained. But the cross recognition method can be applied in our algorithm for preliminary automatic detection

We proposed an automatic detection algorithm, based on Gabor's BPN method. This algorithm detects ED and picks out ED pattern of patient by the cross recognition method firstly. Then if ED is detected, pick out the ED pattern of this patient and its characteristic, train the BPN for this patient by its characteristic. Finally, we utilize this BPN to detect the ED of patient himself.

In this algorithm, the relationship between number of peaks and value of peaks can be fitted to a power function curve from the output curve of BPN, and then parameter  $k$  is derived from the power function curve. Experiments showed that parameter  $k$  could be used to determine a threshold value for detection of ED in EEG automatically.

Because we trained the BPN respectively for each patient by inputting their ED pattern characteristic automatically, the false positive interpretation and the false negative interpretation can be expected to decrease.

## II METHODOLGY AND SYSTEM

### A. Recording

The electronic polar montage is 10-20 international system, and 16-channels scalp recording. A filter was applied to remove possible noise that lies the above 60Hz and below 0.3Hz frequency. Sampling frequency is 200 times/second, and each recording time is about 520 seconds.

Recordings for training basic BPN were interpreted by the expert doctor and were divided three categories: with ED, without ED, recheck or with few ED. The interpretation was regarded as the standard of the automated analysis.

### B. Procedure

First, a segment of patient's EEG is inputted to the basic BPN to determine whether or not ED is included. Then if ED included, a threshold value would be estimated in order to pick out ED pattern better. We train the BPN based on the characteristic of the selected ED pattern, and then recalculate the threshold value based on parameter  $k$ . At last ED of patient's EEG can be automatically detected by the BPN, with the threshold value.

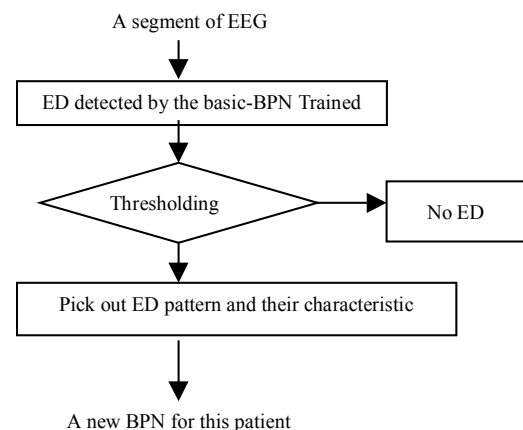


Fig.1. Flow chart of algorithm

### C. BPN

The BPN used to analyze EEG recordings is based on Gabor's<sup>[7]</sup>. The BPN consists of two sub-BPNs, and each sub-BPN consists of three layers: input layer of 16 nodes, hidden layer of 16 nodes, and output layer of 1 node. The error function is set to be 0.01, learn fact 0.01, and momentum fact 0.05. The stand multiple between ED pattern and non-ED pattern is ten. Each node of the input and the hidden layer has connections with all of the nodes of the next layer. There are

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no direct connections between input layer and output layer or among the nodes of the same layer. The output of the BPN was the average of the two sub-BPN outputs.

We take the variant rate of peak as the characteristic. Input of the sub-BPN separate is the 16 channels EEG variant rate before the peak and behind the peak. The BPN output value of ideal ED is equal to 1, and that of non-ED is equal to 0, so the output value of BPN is between 0 and 1.

We select a trained BPN having high recognition rate in order to detect all patients' ED pattern, which be called basic-BPN.

#### D. ED pattern and ED pattern characteristic

The expert doctor selects the ED pattern needed by training basic BPN from classic ED wave, while the other ED patterns are detected and specified by basic BPN. If the output value of self-trained BPN is higher than the threshold value, ED is detected.

We assigned the sharpness as ED characteristic. As ED pattern has picked out, computer look for its peak, left valley and right valley. After site of ED has been ensured, computer calculates the character parameters of ED, which are represented by amplitude-varied rate. Because the width of half peak of ED pattern is different on the same epilepsy EEG, The computer calculates the average half peak width as in (1).

$$\begin{aligned} w'_l &= \sum_{p=1}^N w_{lp} / N \\ w'_r &= \sum_{p=r}^N w_{rp} / N \end{aligned} \quad (1)$$

where  $w'_l$  represents left half peak average width, and  $w'_r$  represents right half peak average width. And  $w_{lp}$  represents the left half peak width of the No. p ED pattern. Computer calculates the amplitude-varied rate of each ED pattern according to average width as in the equation (2).

$$\begin{aligned} v'_{lip} &= v_{lip} * (w'_l / w_{lp}) \\ v'_{rip} &= v_{rip} * (w'_r / w_{rp}) \end{aligned} \quad (2)$$

where  $v_{rip}$  represents amplitude varied rate of the  $i$  channel EEG on the time from peak to right valley.

#### E. Calculating the threshold by parameter $k$

When recognition using BPN, the 16 channels EEG data were input to the basic-BPN, the output values varied with time are got, and a recognition curve is formed. Seek the peak

value of the output curve, count the total of every peak value, and then obtain a curve of the number of the recognition peak value varied with the output value. We call it the curve of the BPN output peak value distribution of recognition (shown in fig. 2). We detect ED from this curve by the cross recognition on the first recognition step.

The BPN output peak value distribution curve (OPVDCR) was fitted with function

$$y = A(k - x)^B \quad (3)$$

where  $x$  stands for peak value,  $y$  stands for counts of peak value,  $k$  stands for the highest peak value when  $y$  equals to 0.

We calculate threshold value by analysis of parameter  $k$  of non-ED and ED curves. We regard the parameter  $k$  of non-ED as the threshold value. On the first step of recognition, parameter  $k$  is obtained from basic-BPN. During the self-detection, the parameter  $k$  can be obtained from this curve of self-trained BPN.

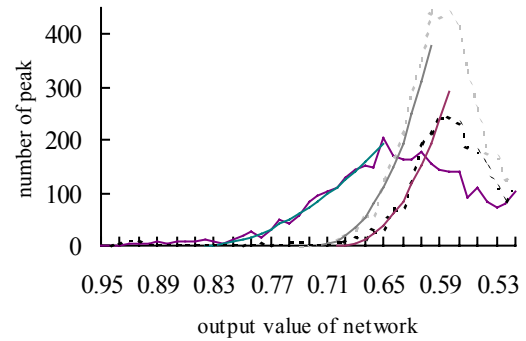


Fig. 2 The OPVDCR and the curve fitted of patient B, C, and D.

### III RESULT

#### 1) The relationship between parameter $k$ and EEG with or without ED

There is a peak in every curve of the BPN output peak value distribution of recognition. When no ED in EEG, the position of the peak is high and closes to the right side; when ED in EEG, the position of the peak is low and close to the left side. In order to analyze this curve, we select the parameter  $k$ . Set if  $k > 0.89$ , then  $k = 0.89$ . The parameter  $k$  of 41 recordings is shown in Fig. 2.

Fig. 3 shows that parameter  $k$  of EEG with ED is more than that of EEG without ED. If the result  $k \geq 0.77$ , ED might be present in EEG. If  $k \leq 0.72$ , ED might be absent in EEG. If  $0.73 \leq k \leq 0.76$ , EEG might be on the edge of presenting ED, or maybe has few ED, or incline to produce ED, in general, those need recheck or prolong the recording time.

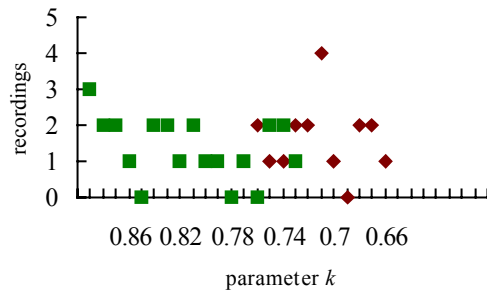


Fig.3 The curve of parameter  $k$  distribute of 41 recordings

■ stands for  $k$  of EEG with ED ◆ stands for  $k$  of EEG without ED

Results also show that parameter  $k$  can eliminate interfere of artifacts. Table 1 shows the effect of artifacts to parameter  $k$ .

TABLE 1

The effect of artifacts on parameter  $k$  of three recordings.

$k$	Patients	B	C	D
No artifacts eliminated		0.84	0.70	0.68
Artifacts eliminated manually		0.83	0.69	0.67
Artifacts eliminated automatically		0.84	0.70	0.68

## 2) Compare automatic detection result with doctor-joint detection result

During recognizing ED of patient A B C, Table 2 shows our method is close to the method of doctor-joint setting threshold.

Parameter  $k$  changed 0.01 if artifacts were not eliminated. It is much lower than the variance of 0.05 for the parameter  $k$  between EEG with ED and EEG without ED. So parameter  $k$  can determine presence or absence of ED in EEG despite artifacts.

TABLE 2

Results of recognition of doctor-joint and automation

	Patient A		Patient B	
	Automate method	Doctor-joint	Automate method	Doctor-joint
Recognition rate	94.6	93.2	90.0	90.0
False positive rate	11.8	7.2	11.8	11.8

## IV DISSCUSION

1) Because the ED pattern of each patient is much deferent from each other, the BPN trained by one patient ED pattern is not fit for another patient.

The advantage of our method is that we train BPN for each patient separately in order that EEG include ED of each patient might get a respective BPN. So we can recognize ED

according to patient himself. Recognition to each patient is self-recognition. High recognition rate is expected to during the large number of clinical interpretation by using this method.

2) Experiments indicated that parameter  $k$  is a significant parameter for determination despite non-ED such as artifacts. Parameter  $k$  shows the fact that ED pattern can make trained BPN output higher value than non-ED pattern. Of course, false recognition will exist. But the experiments show that false positive rate is about ten percents and recognition rate is over ninety percents.

3) This algorithm can eliminate artifacts as well. Many artifacts such as eye blinks, electrode and movement artifacts or EMG, cause difficulty to the automated detection of ED. They are various and some similar to ED. It is difficult to eliminate all artifacts.

In the first recognition step, during cross recognize EEG, artifacts those spatial context are not similar to ED can be eliminated. The rest artifacts can be eliminated based on the difference characters from ED because the kinds of artifacts decrease largely after the cross recognition. Then artifacts remain few.

## V REFERENCES

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